Damped Bloch waves in viscoelastic beam lattice metamaterials via state-space formulation

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Abstract

Beam lattice materials are characterized by a periodic microstructure which realizes a geometrically regular pattern of elementary cells. The linear dispersion properties governing the free propagation of elastic harmonic waves can be studied by formulating parametric discrete models of the cellular microstructure and applying the Floquet-Bloch theory [1]. Within this framework, controlling the wave propagation by means of energy dissipation mechanisms is a major issue of theoretical and practical interest. To this end, a general dynamic formulation is presented for determining the dispersion properties of mechanical metamaterials modeled, in a two-dimensional space, as locally resonant beam lattices with generic coordination number. The mechanism of local resonance is realized by tuning periodic auxiliary oscillators viscoelastically coupled with the beam lattice microstructure. The free propagation of the damped waves of the translational and the rotational motions is described by an enlarged linear homogeneous system of equations obtained – first – by approximating the kernel of the 3 integral-differential viscoelastic relationships with a Prony series truncated at the nth term and – second – by adding 3n viscoelastic states whose dynamics are governed by auxiliary first order differential equations [2]. The complex-valued branches of the dispersion spectrum are determined and parametrically analyzed for a beam lattice characterized by periodic hexagonal cells [3]. The occurrence of 3n pure-damping spectral components, associated with waveforms strongly polarized in the added states, is highlighted and discussed. Finally, the forced responses to harmonic monofrequent external excitations due to point forces and couples, respectively, are investigated in the frequency and time domains. The metamaterial responses to non-resonant, resonant and quasi-resonant external forces and couples, are then compared and discussed from a qualitative and quantitative point of view.

References

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Arena, A., Bacigalupo, A., Lepidi, M. (2021). Damped wave propagation in viscoelastic metamaterials through added state formulation. submitted.

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